63-4

Contract No. AF 33(657)-8298

QUARTERLY REPORT NO. FIVE

INVESTIGATION OF NON-EQUILIBRIUM IONIZATION FOR MHD ENERGY CONVERSION

15 March 1963 to 15 June 1963

Project 8173
Task 817306
Reqn. No. 214-B97
Issued to: General Electric Company

Project Scientist: Dr. G. W. Sutton
Telephone Number: (Area 215) 969-2674

Space Sciences Laboratory
Missile and Space Division
Valley Forge Space Technology Center
General Electric Company
Valley Forge, Penna.

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The work covered by this report was accomplished under Air Force Contract 33(657)-8298 but this report is being published and distributed prior to Air Force review. The publication of this report, therefore, does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

The work reported herein was sponsored by the Air Force AeroPropulsion Laboratory of the Aeronautical Systems Division. Mr. Don R. Warnock, Static Energy Conversion Section, ASRPP-2, Extension 22208, is the cognizant engineer for the Air Force.

SUMMARY

This fifth quarterly reports accomplishments during the period 15 March 1963 - 15 June 1963 on a theoretical and applied research program directed toward prolonging the lifetime of magnetohydrodynamic (MHD) energy converters by reducing the necessary operating temperatures to the range of 1000 to 2000°K. The process of interest is the use of the self-induced electric field in the MHD generator for electrical break-down of appropriate working fluids of interest. Work at present is directed toward the use of Potassium for Rankine (vapor) cycles and Argon plus Cesium for studying the basic parameters of the break-down, although the results are applicable to gas (Brayton) cycles with certain nuclear reactors.

SIGNIFICANT ACCOMPLISHMENTS

During the present report period, fabrication and erection of the primary system for the potassium vapor blowdown experiment was completed and fully certified for operation.

Assembly of auxiliary sub-systems, instrumentation and control functions, and the MHD channel inserts progressed satisfactorily.

Design of the alkali metal vapor closed loop was initiated. The requirements and characteristics of the loop components and instrumentation were defined. Design calculations and construction drawings of many of the major loop components were prepared.

Following a series of cold runs to establish the fluid dynamic behaviour of the system, the first full-scale hot run was conducted in the argon - cesium continuous flow facility.

I. LIQUID METAL VAPOR EXPERIMENT(M-5)

During the present report period, fabrication and erection of the potassium vapor blowdown system piping was completed. The completed primary system was inspected by a representative of the Space Technology Center's insurance underwriters and was fully certified for operation. An assembly drawing of the as-built piping system is shown in Figure 1. A photograph of the blowdown loop positioned in the new MHD Power Generation Laboratory is presented in Figure 2.

A stainless steel nozzle for insertion in the transition joint-nozzle spool piece was designed to achieve Mach 3.2 at the entrance to the MHD generator channel. This nozzle (see Figure 3) has reached final machining stages.

The two total pressure transmitters and the differential pressure transmitter were mounted on support brackets integral to the piping system (see Figure 4). The blowdown tank pressure probe has been welded in position, but positioning of the other pressure probes must await completion of the nozzle insert to assure proper location of the spool piece wall taps.

The high density alumina inserts for the MHD channel were received from the vendor. Bench mock-up of the channel using a short shroud section has demonstrated the feasibility of the proposed assembly technique. Slight edge grinding of the inserts will be required to affect proper assembly in the shroud. A bench layout of the channel inserts is displayed in Figure 5. This channel will be assembled in the test section thimble in accord with the arrangement displayed in Figure 6. The several items associated with the electrode assemblies and cartridge heater terminals are being prepared.

The instrument console and motor control center were assembled. The blowdown tank temperature control, heater sheath temperature limit control, multi-point temperature recorder, pressure indicator-recorder-controller, four pen continuous temperature recorder, and vacuum system instrumentation were mounted in the console. Installation of additional instruments and alarm systems is proceeding.

Utility services to meet the blowdown system electrical, pneumatic, and cooling water demands were installed. With the completion of these installations, wiring of the blowdown tank heaters and instrument-control console and installation of pneumatic and cooling water piping can now proceed.

Without continuous injection of potassium into the blowdown tank, the upstream temperature and pressure of the potassium vapor will continuously vary with time during the blowdown process. An estimate has been obtained for the elapsed blowdown time for the potassium vapor pressure to decrease to the absolute pressure in the tank; that is, until incipient potassium condensation. The calculations were performed under the assumption that the potassium vapor behaves as an ideal gas undergoing an adiabatic-isentropic expansion. The results of this calculation are displayed in Figure 7. The region to the left of the curve represents the operating region; that is, the region in which the vapor pressure exceeds the total pressure in the tank.

II. ALKALI METAL VAPOR LOOP (M-6)

Design of the alkali metal vapor closed loop was initiated. During the initial stage in the design program, the requirements and characteristics of the loop components and instrumentation were defined. The system was to be capable of generating 2 pounds/minute of saturated potassium vapor at temperatures ranging from 1700°R to 2000°R (6.1 to 29.0 psia). After adding several hundred degrees of superheat (2500°R maximum), the vapor would be expanded through a nozzle to attain supersonic velocities at the entrance to the MHD generator. The vapor discharge from the generator channel would be desuperheated and condensed in air-cooled units; the condensate returning to the boiler by means of an electromagnetic pump. Auxiliary systems would include a by-pass purification system capable of 10 loop volume through-puts per hour, a potassium transfer system, and vacuum and cover gas systems. The system would be fully instrumented for both steady-state and transient operation with minimum operator coverage. Based on these design criteria, a flow schematic was prepared (Figure 8) and mechanical component and instrumentation and control function specification lists were established.

Design calculations for the potassium boiler were completed. On the basis of the maximum required operating temperature and vapor generation rate, 316 stainless steel was selected as a likely candidate for the construction material and a high flux, immersion-type heater was selected to provide the approximately 30 KW heat input requirement.

A vessel meeting these specifications and conforming to Section I (Power Boilers) of the ASME Boiler and Pressure Vessel Code was conveniently designed using an 8-inch, schedule 160 seamless pipe in conjunction with a standard 8-inch torispherical head and 8-inch x 2 1/2-inch concentric reducer for the upper and lower plenums, respectively. Overall height of the vessel is approximately 14-inches. Heat input is supplied from twelve, 5/8-inch diameter, Inconel-sheathed "Firerod" heaters, each delivering 4.7 KW at 230 volts over an effective heated length of as little as 5 1/2-inches. Six heaters enter the vessel through the top head at 60^{o} intervals on a 6-inch bolt circle. The remaining heaters are stepped on 1 3/8-inch centers at 60^{o} intervals up the shell periphery. The cold zone, that is, unheated portion of the heater both internal and external to the vessel was made arbitrarily long to assure that the vertical heater hot zones are submerged in the liquid phase at all times and to avoid heater lead burn-out. To provide leak-proof construction, the heaters are seal-welded to bosses in the vessel wall and head by means of welding collars which are integral to the units. Design details of the vessel are shown in Figure 9; the high flux, immersion-type heaters will be fabricated in accordance with Figure 10. By dividing the heat load among twelve heaters, balanced 3-phase operation can be conveniently achieved with approximately 85% margin in capacity. Such an arrangement in conjunction with autotransformers will permit operation at reduced applied voltage (approximately 120 volts) and result in grossly increased heater life expectancy.

A complete stress analysis of the potassium boiler was performed. The design meets all requirements of the Code for operation at 2000°R and 100 psig (minimum Code design pressure). Although the calculations were performed for 316 stainless steel as the construction material, a high strength alloy (Haynes 25 or Inconel X) may be employed. The actual use of a material having greater temperature - allowable working stress characteristics will not, of course, negate the validity of the vessel's conformance to the Code; rather, for the same configuration, it will result in a structure having greater safety margin (allowance for mechanical strength and for corrosion) and, thus, increased operating lifetime.

Calculations governing the engineering design of an induction-heated type superheater have been performed. These calculations display the electromagnetic coupling between the induction coil and heater element and the heat transfer characteristics between the element and the vapor; and, thus, predict the current distribution and power absorption required to produce varying degrees of superheat. Armed with these analytical results, the design of an element and coil to achieve a maximum vapor temperature of 2500°R can now proceed.

Design calculations for the primary system condenser-cooler were completed. The design philosophy adopted was not intended to obtain optimum performance characteristics for the unit but rather to assure adequate heat removal capability and flexibility. The condenser-cooler will be air-cooled and operate between 1550°F and 900°F over three thermodynamic regimes, namely: 1) superheated region, 2) vapor condensing region, and 3) liquid cooling region. The condenser-cooler will be fabricated from 3/4-inch seamless stainless steel tubing (type 316) arranged as 10 coil turns, 15 1/2-inches in diameter, on a 2 1/2-inch coil pitch, supported in a baffled plenum. This unit will reject approximately 35 KW of heat at an air displacement volume of 830 cubic feet/minute. Air cooling will be provided by a centrifugal blower delivering a maximum of 1000 CFM at an estimated static pressure of 1" W. C. The blower will be direct driven by a variable speed magnetic drive arranged for automatic adjustment to satisfy air delivery rate requirements. A design drawing of the condenser-cooler coil and baffled plenum is presented in Figure 11.

The hot trap in the purification loop was designed as an in-line vertical unit which accepts roughly 90% of the total pump flow. Its purpose is to getter oxygen, carbon and nitrogen from the potassium to reduce corrosion and to prevent formation and accumulation of the superoxides on the construction materials of the loop. The active or getter material is Cb-1Zr alloy. As shown in Figure 12, the columbium alloy in sheet form is corrugated and rolled spirally in short cylinders. The cylinders are packed into a 2 1/2-inch by 24-inch long, 316 stainless steel tubular hot trap. Concentric reducers are used at the ends of the hot trap to make up to the purification loop piping and allow complete drainability.

The sump tank and accumulator (Figures 13 and 14, respectively) were designed in accordance with Section VIII (Unfired Pressure Vessels) of the ASME Boiler and Pressure Vessel Code for operation at 1000°F and 100 psig. The sump tank was sized to accept a potassium volume estimated at twice the required loop charge. Oversizing is necessary to assure that sufficient relatively cool (say 450°F) liquid is present in the tank to prevent thermal shocking of the vessel in the event of an emergency hot dump. Operating level in the sump tank will be monitored by four spark plug-type level probes. This is done by adapting standard automotive spark plugs (with center rod tips extended to various lengths) to the vessel. One side of a transformer having a 6 volt secondary is connected in series with a 6 volt lamp (in parallel with a relay) and the spark plug. The loop is grounded, so that when liquid covers the spark plug, the circuit is completed and the light and relay are actuated. This relay can be used to actuate an audible alarm system and/or control function.

The accumulator serves both as a reservoir to compensate for thermal expansion or contraction of the loop charge during heat-up or cool-down and as a surge tank to dampen transients in pump suction pressure during steady-state operation.

In preparation for initiating system layout drawings, an isometric sketch of the loop was prepared. The technical illustrator's conception of the system based on the isometric sketch is displayed in Figure 15.

The operating lines superimposed on the temperature-entropy diagram shown in Figure 16 depict the alkali metal vapor cycle. From this diagram it is readily seen that inappropriate selection of the vaporization pressure (line 2-3-4-5 is an isobar) in combination with expansion to too high a Mach Number (line 5-6) can result in an MHD generator entrance condition (point 6) lying below the potassium vapor pressure line. To determine the possible operating limits, screening calculations of anticipated MHD generator performance were prepared. For example, on vaporizing 15 grams/sec of potassium at 6.1 psia (1700^{o}R), superheating of the vapor to 2500^{o}R and isentropic expansion to Mach 1.5, the MHD channel inlet pressure will drop to 1.5 psia (which borders on incipient condensation). At the conditions described (and assuming that the vapor does not actually condense), a plasma conductivity of 35 mhos/meter could be achieved in a magnetic field of about 30 kilogauss. The resultant power density would be approximately 0.1 kilowatts/cm^3. Operation at higher vaporization pressures or higher Mach Numbers (or combinations of the two) would certainly result in vapor condensation. Since the operation of a wet potassium vapor generator is not a priori in conflict with the magnetically induced non-equilibrium ionization process, a theoretical study of the effect of wet potassium vapor (droplets) on non-equilibrium electron heating (and, generator performance) has been undertaken.

III. THE ARGON-CESIUM CONTINUOUS FLOW FACILITY (M-4)

A series of cold runs were conducted in order to obtain the fluid dynamic data, necessary in order to correctly evaluate the data obtained from the full scala MHD runs. The average friction factor during the hot runs will be around 0.008. During the cold runs the Mach number at the exit of the nozzle (measured by means of a mercury monometer placed across the nozzle) ranged from 0 to .45. The corresponding Mach numbers at the channel exit ranged from 0 to .82. Flow rates of argon measured by means of a rotameter situated prior to the heater, and by means of a pitot tube situated at the channel exit, agreed within 2%.

During the hot runs, the Mach number through the electrode section will vary from 0.6 at the entrance to 0.75 at the exit.

Since the magnetic field strength will be 20,000 gauss, and the average plasma flow velocity will be around 400 meters/second, the induced electric field will be around 800 volts/meter. In the absence of huge sheath drops, the voltage drop developed across the channel will be around 24 volts. If only the equilibrium conductivity 8×10^{-3} mho/meter exists, the short circuited current will be 0.6 milliamps for the conditions:

$$T_o = 1200^{\circ}K$$
$$P_o = 15 \text{ psig}$$
$$M_1 = 0.6$$

If the plasma reaches the best non-equilibrium state, the conductivity will be around 600 mhos/meter and short circuited currents around 40 amps will be observed. Thus it will be immediately obvious if a state of non-equilibrium exists within the plasma.

By short circuiting a galvanometer to each of three electrode pairs within the test section, a permanent record of current and noise may be obtained as long as the conductivity is less than 0.25 mhos/meter and the noise frequency is less than 300 cps. If the conductivity is more than 0.25 mhos/meter, the galvanometer deflection will pass off the recording chart and the MHD test section panel will supply the means of obtaining the data. A 0.1 amp fuse will protect each galvanometer. The low scale calibration curves are shown in Figure 17. Figure 18 shows typical charts obtained with a sine wave generator. Although the chart drive is not constant, (as indicated by the apparent compression in the time scale), the timing lines will supply an adequate reference. Galvanometers #5, #11 and #25 will be attached to power electrodes (in the test section). Galvanometers #25, #45, and #52 will be used to monitor the current from external batteries downstream and just out of the magnetic field region. These measurements will provide data necessary in order to calculate rates of deionization.

The first full scale hot run was conducted with the Argon-Cesium MHD Continuous Flow Facility. Having been purged with argon for two days, the oxygen content was less than 10 ppm in the MHD heater, the MHD generator, and in the Cesium Injection System. The MHD heater was brought up to the correct operating power, (60 KW), within the first 30 seconds. During the first 10 seconds of heating, the oxygen content in the MHD generator rose to around 4000 ppm but then fell rapidly back to less than 10 ppm for the remainder of the run indicating that after initial outgassing, the outgassing rate is completely negligible compared to the main stream flow rate.

During the first 45 seconds of operation the temperatures within the heater, the nozzle and the MHD test section began to rise as predicted and the cesium injection system was prepared for injection by filling the syringe with liquid cesium. The time required to fill the syringe with 15 grams of cesium was 30 seconds. By this time the argon stream temperature at the nozzle entrance was 1575°K ± 15 K°. The mass flow rate of argon was 0.16 pounds/second. (After 1 minute of operation, the average outside surface temperature of the aluminum oxide tubes, surrounding the molybdenum mesh heater, was less than 250°C, indicating that heat conduction losses are negligible.)

However, after 1 minute and 15 seconds of operation, the heater current began to fluctuate and one of the heater leads open circuited; the run was then discontinued. Instead of being injected into the system, the cesium was injected into a beaker of oil and allowed to slowly react with amyl alcohol.

The hot end of the molybdenum mesh heater was disassembled. The point of open circuit occurred at the contact points between the mesh and the 800 ten mil lead wire situated in the argon flow. The end of the mesh has now been brought out and directly connected to large copper bar clamps. During the hot run, the argon cooling of the copper clamps was more than adequate. However, since the geometry has now been changed, a new heat transfer analysis was performed to determine where and what value would be the maximum temperature in the copper electrode lead. Temperatures in the new copper bars will stay below the 800°C (about 270 C° below the melting point). During the initial reassembly of the heater, (while the alumina cement was drying), the cesium injection system was modified to permit operation of all electrical components inside as well as from outside of the dry box. The second hot run will be conducted within several days.

The MHD Continuous Flow Facility is shown in Figures 19 - 23. Figure 19 shows the Pre-ionization Control Panel, the MHD Test Section Panel, the Millivolt Temperature Recording System. (The Dual Pen Recorder continuously records four temperatures. The bottom recorder is a 24 multipoint recorder). The Cesium Injection System is shown in Figure 20. The high voltage pre-ionization system, the Hall Voltage Panel and the De-ionization Rate Panel are shown in Figure 21. The two oscilloscopes permit continuous observation of the Hall voltage and the induced voltage between the twelfth electrode pair. In the background are seen the magnet power control and the saturable core reactor control for the MHD Heater System. Figure 22 shows the Oxygen Analyzer System, in front of the L-158 magnet, the exhaust drum, and the optical pyrometer used to measure the exit temperature of the molybdenum mesh heater. Figure 23 shows the MHD Electrode Connection Panel on the right and the mercury monometer bank on the left in front of the MHD Heater Tank. Underneath the MHD Heater Tank can be seen the step-down transformer necessary to provide a low voltage-high current power supply to the Molybdenum Mesh Heater.

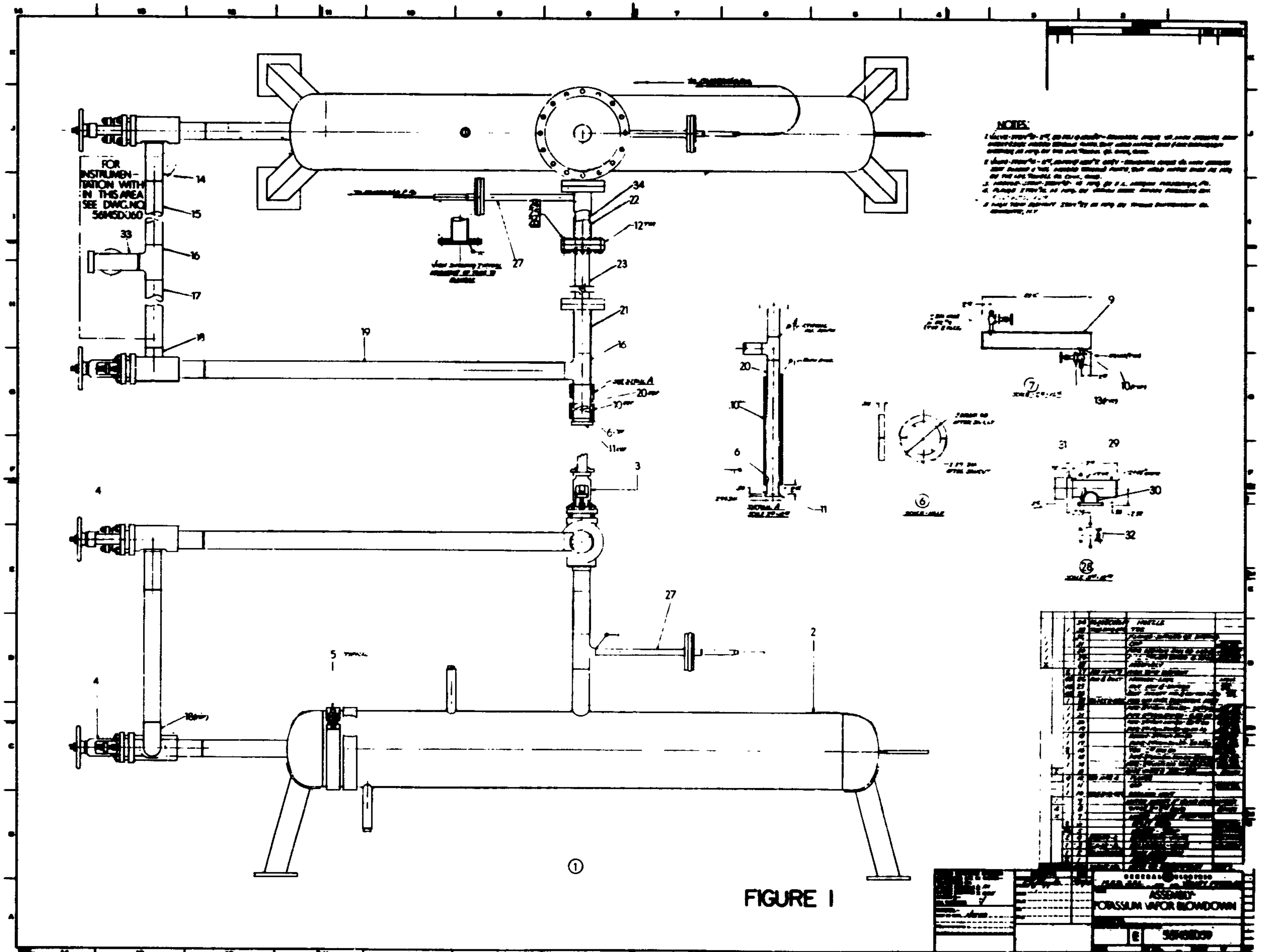

FOR INSTRUMENTATION WITHIN THIS AREA SEE DWG.NO.
NOTES:
ASSEMBLY-
POTASSIUM VAPOR BLOWDOWN

FIGURE I

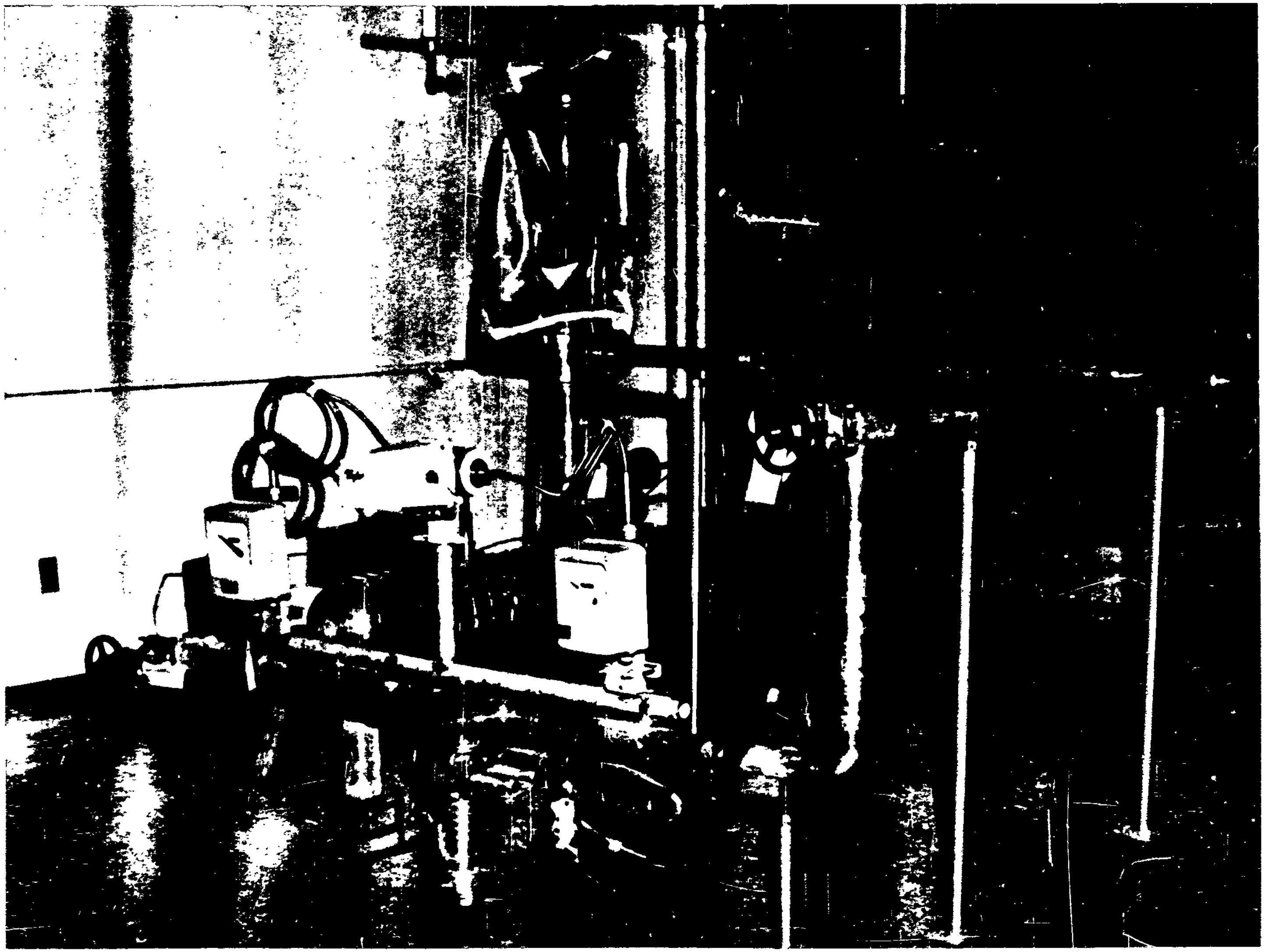


Figure 2

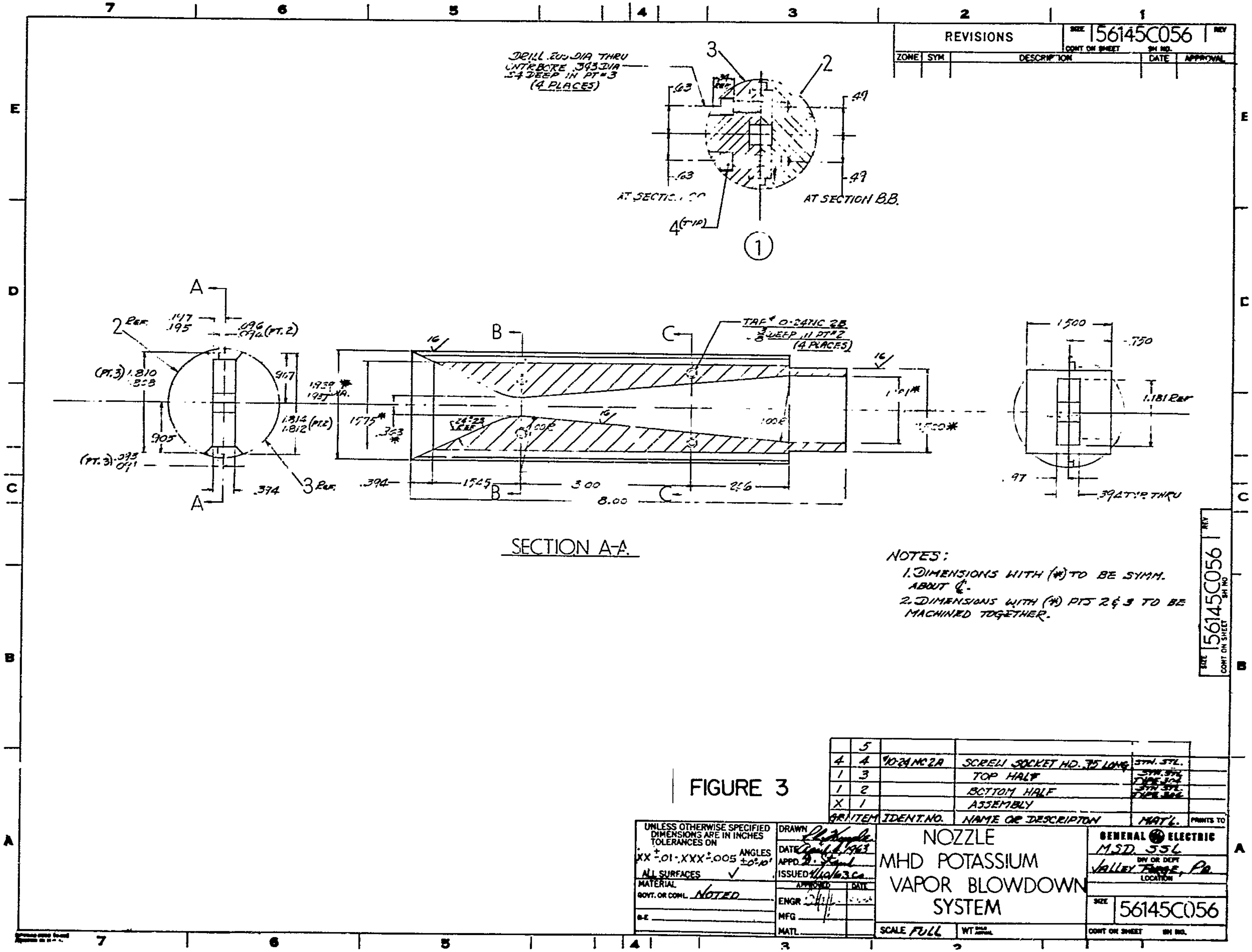
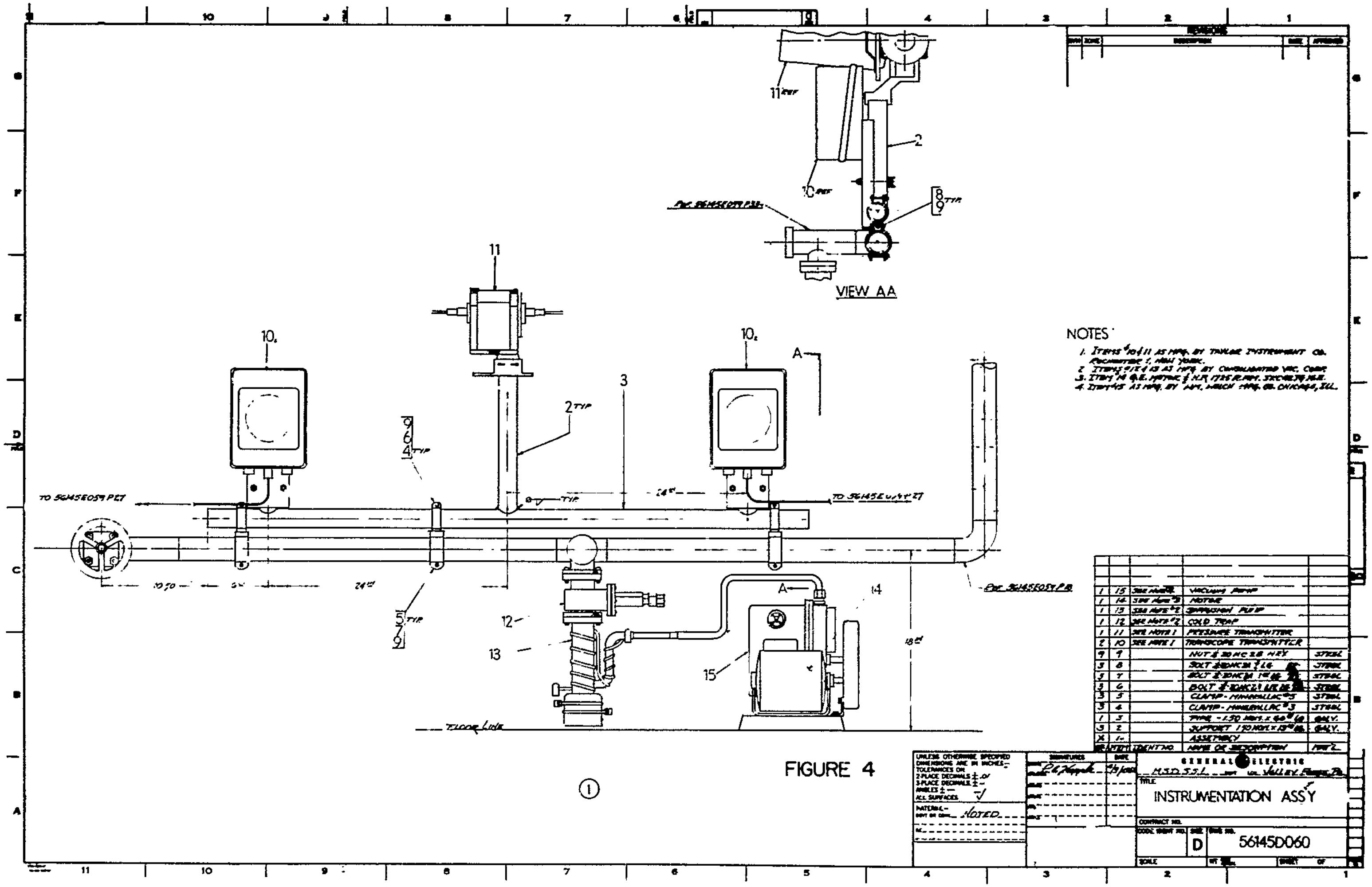

REVISIONS
56145C056
DRILL .200 DIA THRU
CNTRBORE .393 DIA
.34 DEEP IN PT #3
(4 PLACES)
AT SECTION B.B.
SECTION A-A
TAP 0-24NC 2B
3/8 DEEP 11 PT #2
(4 PLACES)
8.00
3.00
.394
.97
.394 TYP THRU
1.181 REF
1.500
.750
NOTES:
1. DIMENSIONS WITH (*) TO BE SYMM. ABOUT ℄.
2. DIMENSIONS WITH (*) PTS 2 & 3 TO BE MACHINED TOGETHER.
10-24 NC 2A
SCREW SOCKET HD. .75 LONG
TOP HALF
BOTTOM HALF
ASSEMBLY
IDENT. NO.
NAME OR DESCRIPTION
MAT'L.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
.XX ±.01 .XXX ±.005 ANGLES ±0°10'
ALL SURFACES
MATERIAL
NOTED
NOZZLE
MHD POTASSIUM
VAPOR BLOWDOWN
SYSTEM
GENERAL ELECTRIC
M.S.D. 55L
Valley Forge, Pa
SCALE FULL
56145C056

FIGURE 3



VIEW AA
NOTES
1. ITEMS 10 & 11 AS MFG. BY TAYLOR INSTRUMENT CO. ROCHESTER 1, NEW YORK.
2. ITEMS 12 & 13 AS MFG. BY CONSOLIDATED VAC. CORP.
3. ITEM 14 G.E. MOTOR 1/2 H.P. 1725 R.P.M.
4. ITEM 15 AS MFG. BY W.M. WELCH MFG. CO. CHICAGO, ILL.
VACUUM PUMP
MOTOR
DIFFUSION PUMP
COLD TRAP
PRESSURE TRANSMITTER
TRANSCOPE TRANSMITTER
ASSEMBLY
NAME OR DESCRIPTION
GENERAL ELECTRIC
M.S.D. S.S.L.
VALLEY FORGE, PA.
INSTRUMENTATION ASSY
D
56145D060
FLOOR LINE

FIGURE 4

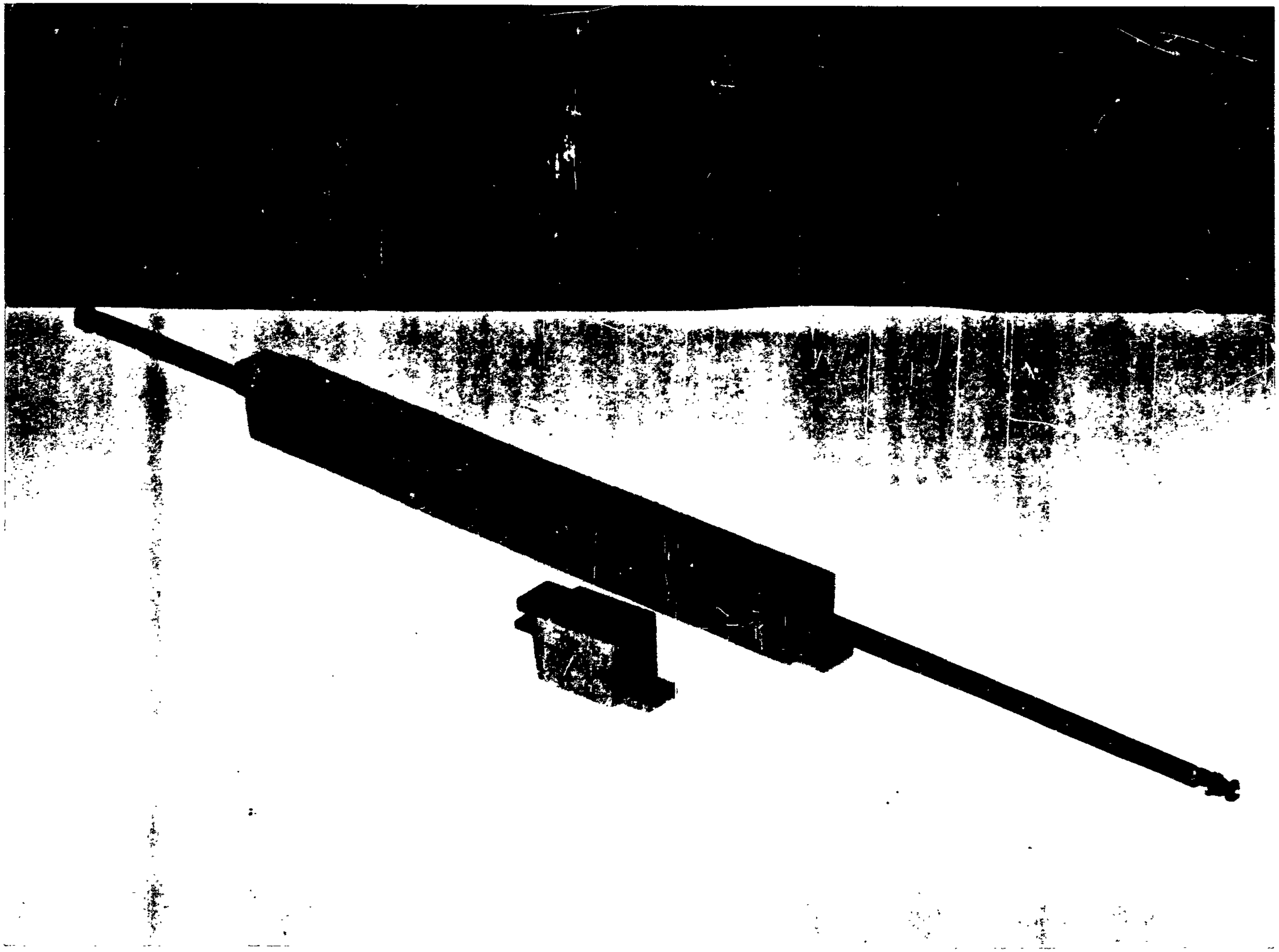
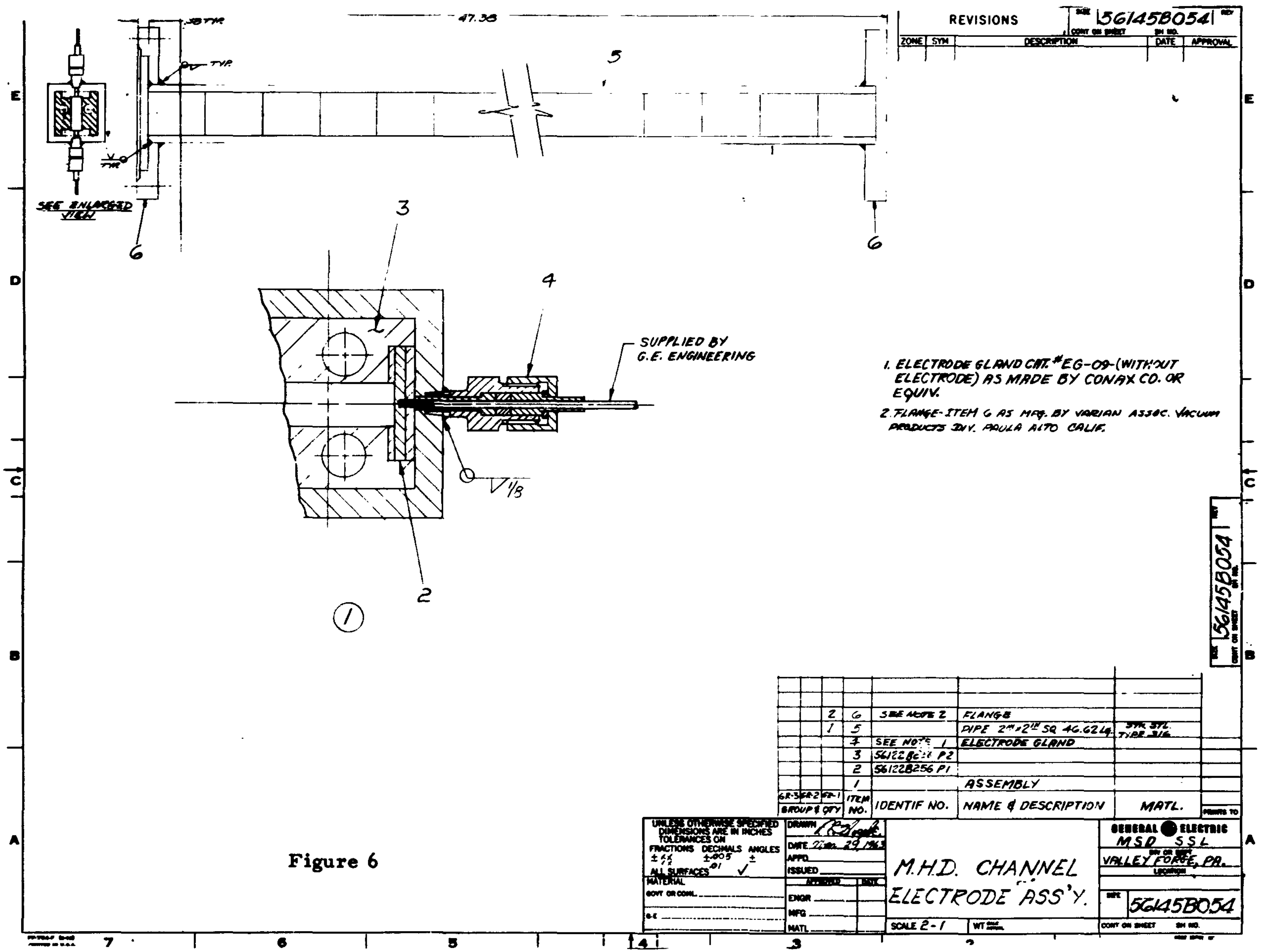


Figure 5



REVISIONS
56145B054
ZONE
SYM
DESCRIPTION
DATE
APPROVAL
47.38
5
6
3
4
2
1
SEE ENLARGED VIEW
SUPPLIED BY G.E. ENGINEERING
1. ELECTRODE GLAND CAT. #EG-09-(WITHOUT ELECTRODE) AS MADE BY CONAX CO. OR EQUIV.
2. FLANGE-ITEM 6 AS MFG. BY VARIAN ASSOC. VACUUM PRODUCTS DIV. PAULA ALTO CALIF.
2 | 6 | SEE NOTE 2 | FLANGE
1 | 5 | PIPE 2"×2" SQ 46.62 Lg. | SST. STL. TYPE 316
4 | SEE NOTE 1 | ELECTRODE GLAND
3 | 56122B256 P2
2 | 56122B256 P1
1 | ASSEMBLY
GROUP & QTY | ITEM NO. | IDENTIF NO. | NAME & DESCRIPTION | MATL.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
±.005
ALL SURFACES
MATERIAL
DRAWN
DATE
APPD.
ISSUED
ENGR
MFG
MATL
GENERAL ELECTRIC
MSD SSL
VALLEY FORGE, PA.
M.H.D. CHANNEL ELECTRODE ASS'Y.
SCALE 2-1
56145B054

Figure 6

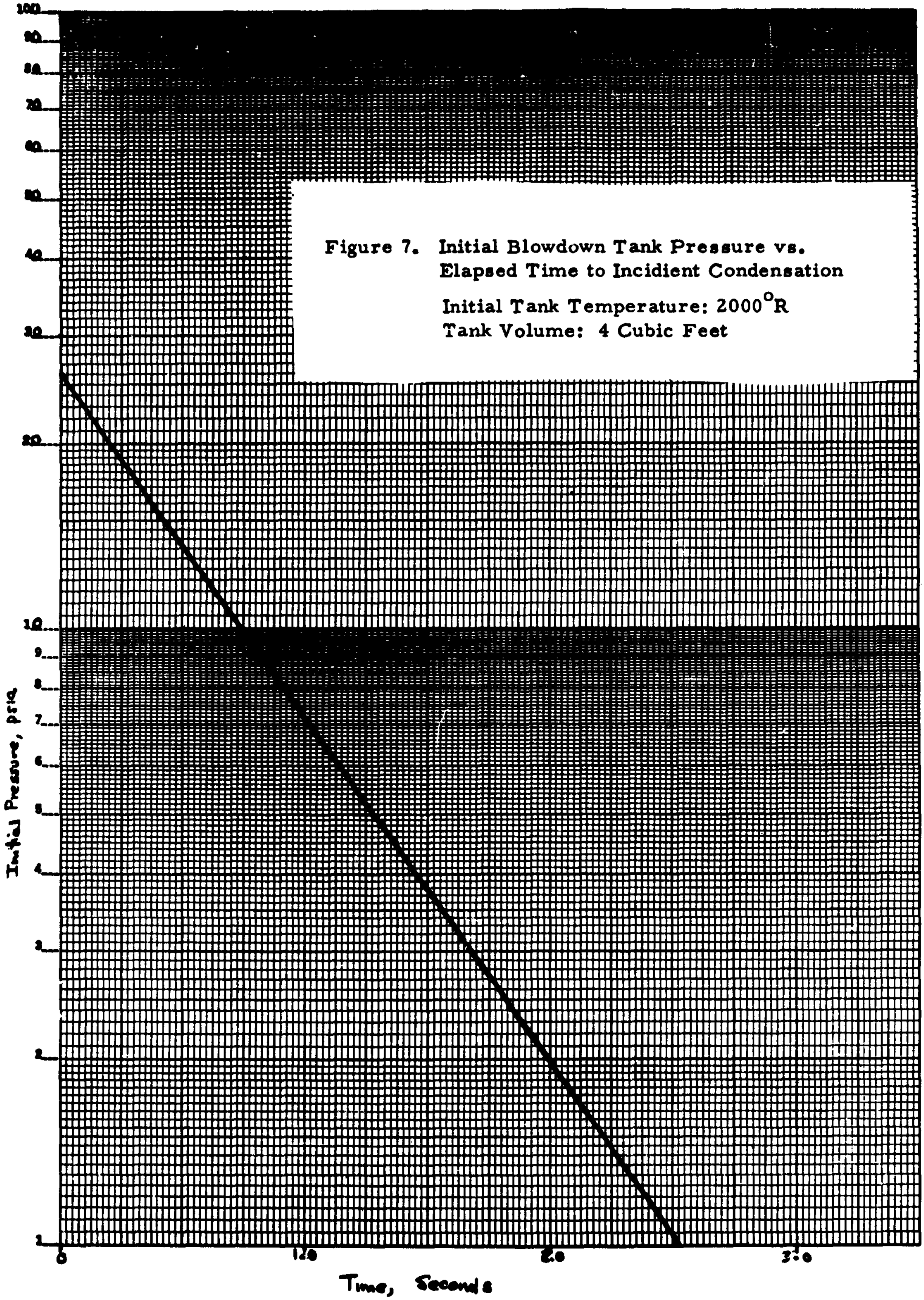


Figure 7. Initial Blowdown Tank Pressure vs. Elapsed Time to Incidient Condensation

Initial Tank Temperature: 2000°R
Tank Volume: 4 Cubic Feet

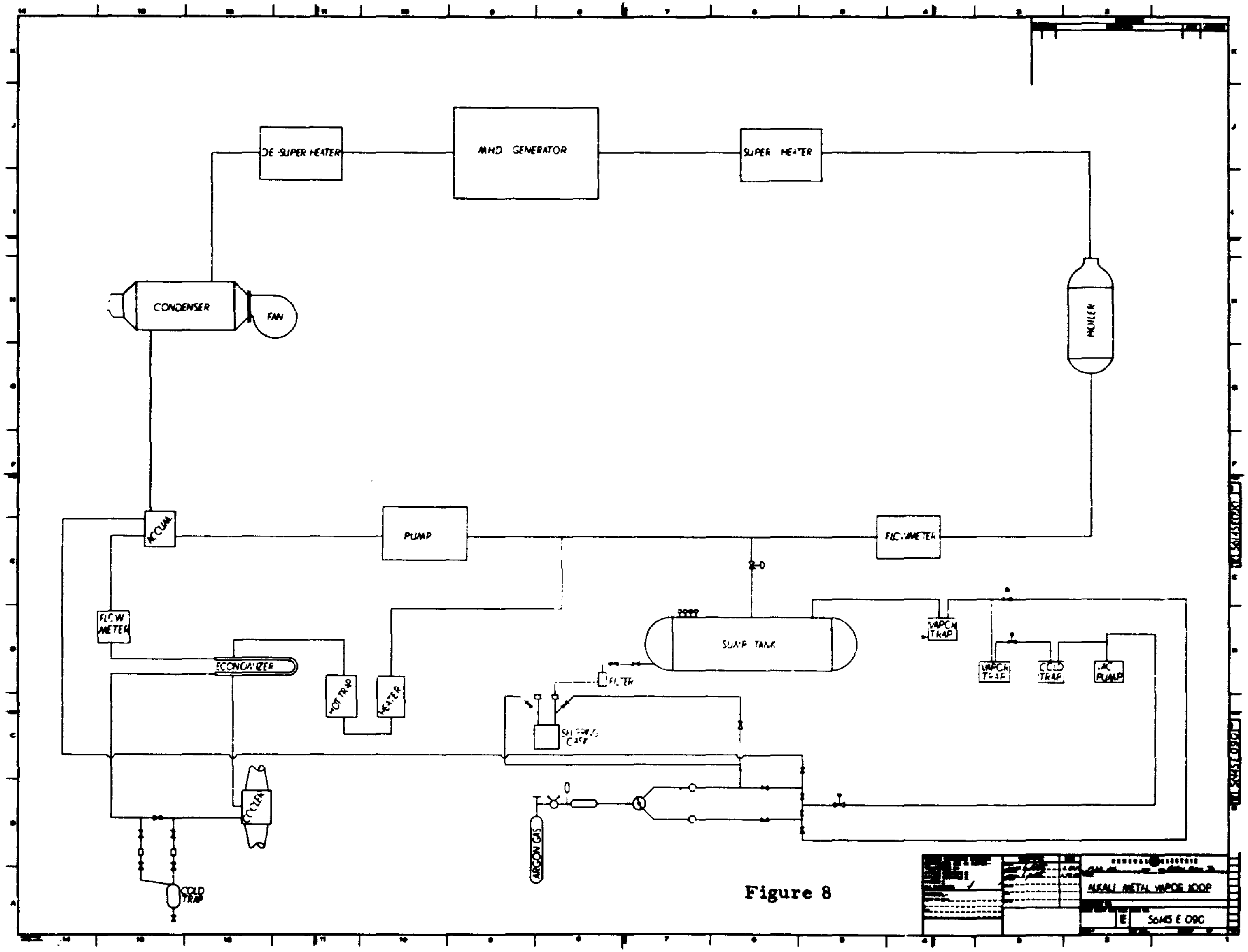
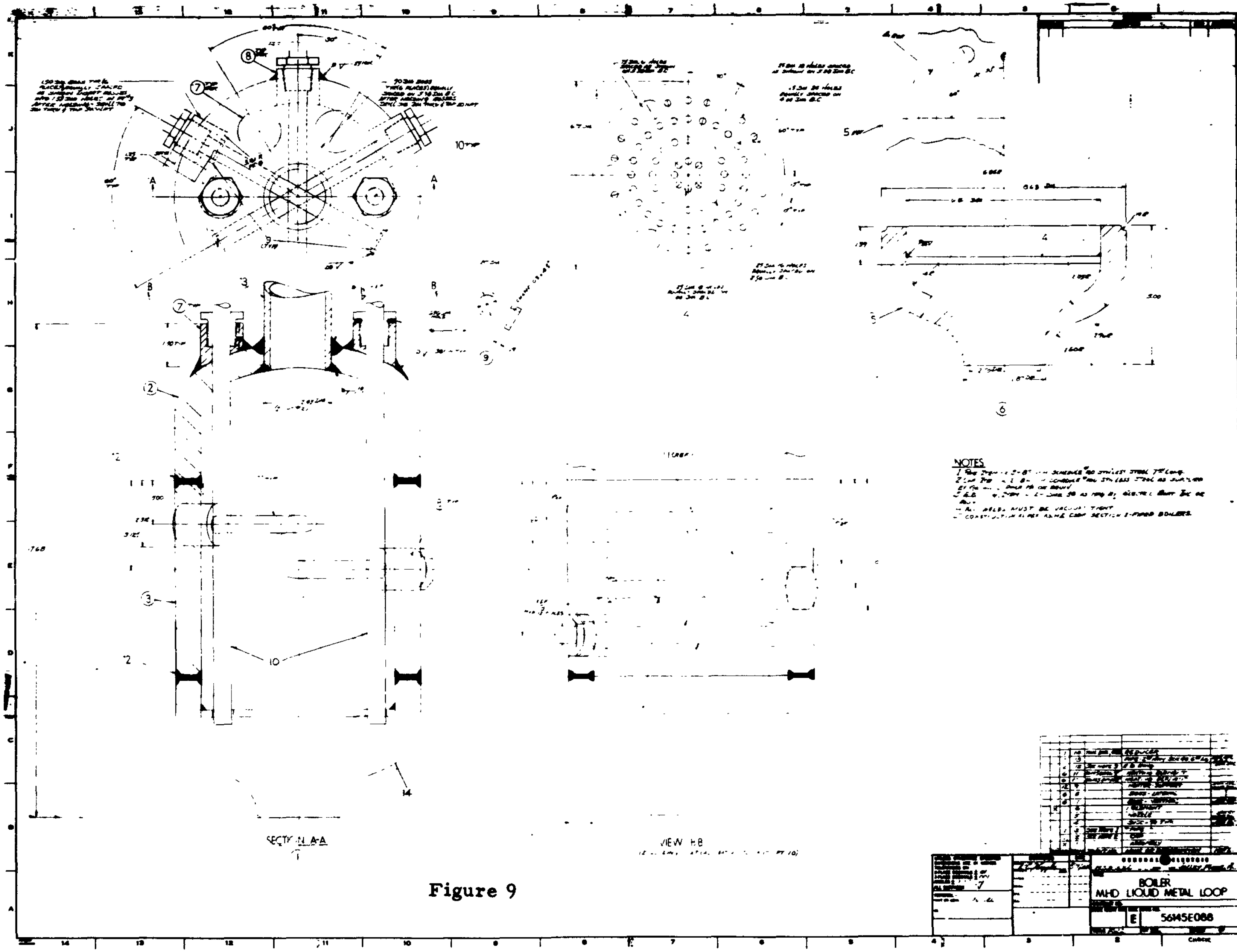

DE SUPER HEATER
MHD GENERATOR
SUPER HEATER
CONDENSER
FAN
BOILER
ACCUM
PUMP
FLOWMETER
FLOW METER
ECONOMIZER
HOT TRAP
HEATER
SUMP TANK
FILTER
VAPOR TRAP
COLD TRAP
ARGON GAS
COOLER
ALKALI METAL VAPOR LOOP
56MS E 090

Figure 8



NOTES
SECTION A-A
VIEW B-B
BOILER
MHD LIQUID METAL LOOP
E
56145E088

Figure 9

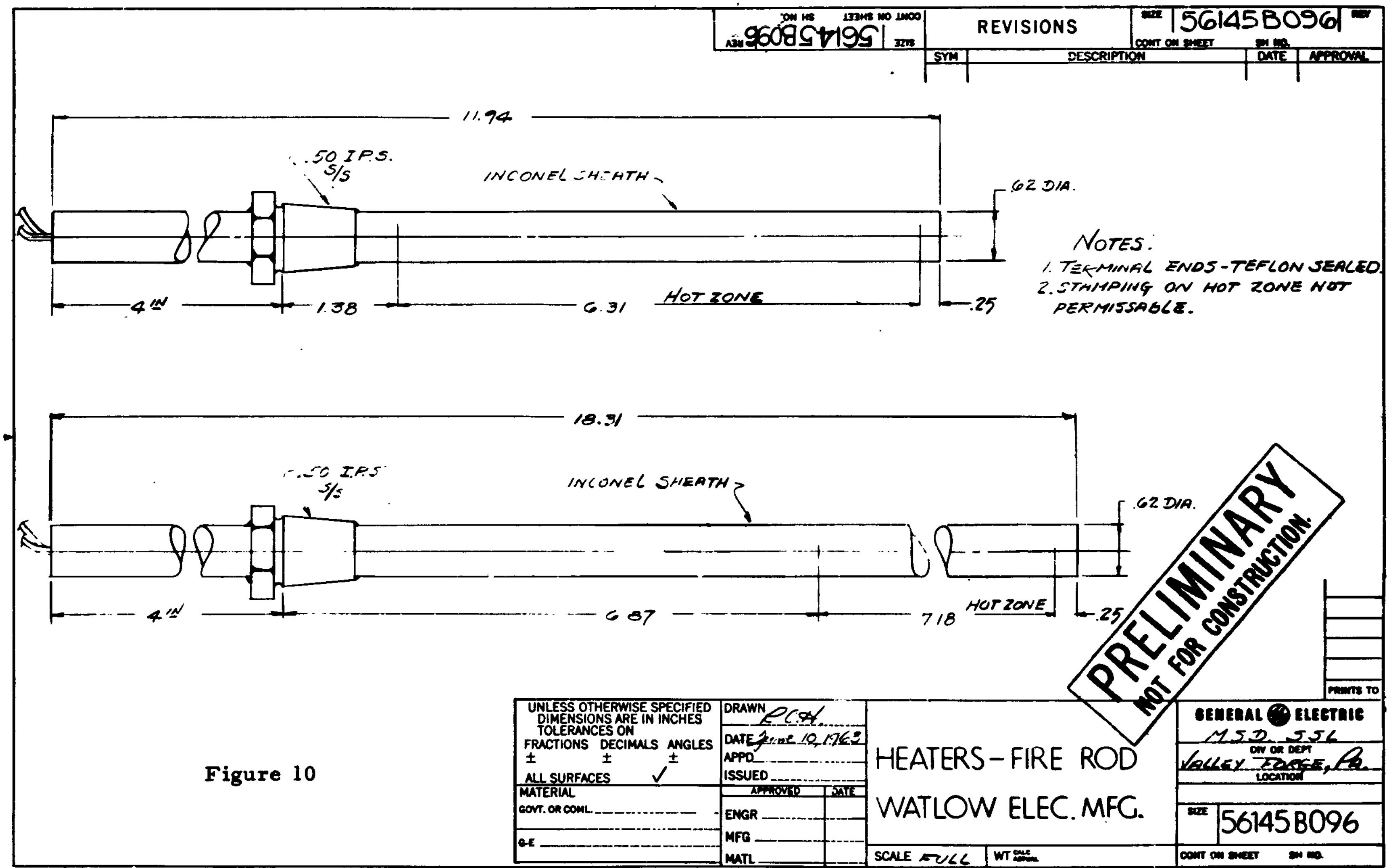

REVISIONS
SIZE 56145B096 REV
CONT ON SHEET SH NO.
SYM DESCRIPTION DATE APPROVAL
11.94
.50 I.P.S. S/S
INCONEL SHEATH
.62 DIA.
NOTES:
1. TERMINAL ENDS-TEFLON SEALED.
2. STAMPING ON HOT ZONE NOT PERMISSABLE.
4 IN
1.38
6.31
HOT ZONE
.25
18.31
.50 I.P.S. S/S
INCONEL SHEATH
.62 DIA.
4 IN
6.87
7.18
HOT ZONE
.25
PRELIMINARY
NOT FOR CONSTRUCTION.
PRINTS TO
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
ALL SURFACES ✓
MATERIAL
GOVT. OR COML.
G-E
DRAWN RCH.
DATE June 10, 1963
APPD
ISSUED
APPROVED DATE
ENGR
MFG
MATL
HEATERS - FIRE ROD
WATLOW ELEC. MFG.
SCALE FULL
WT
GENERAL ELECTRIC
M.S.D. SSL
DIV OR DEPT
Valley Forge, Pa.
LOCATION
SIZE 56145B096
CONT ON SHEET SH NO.

Figure 10

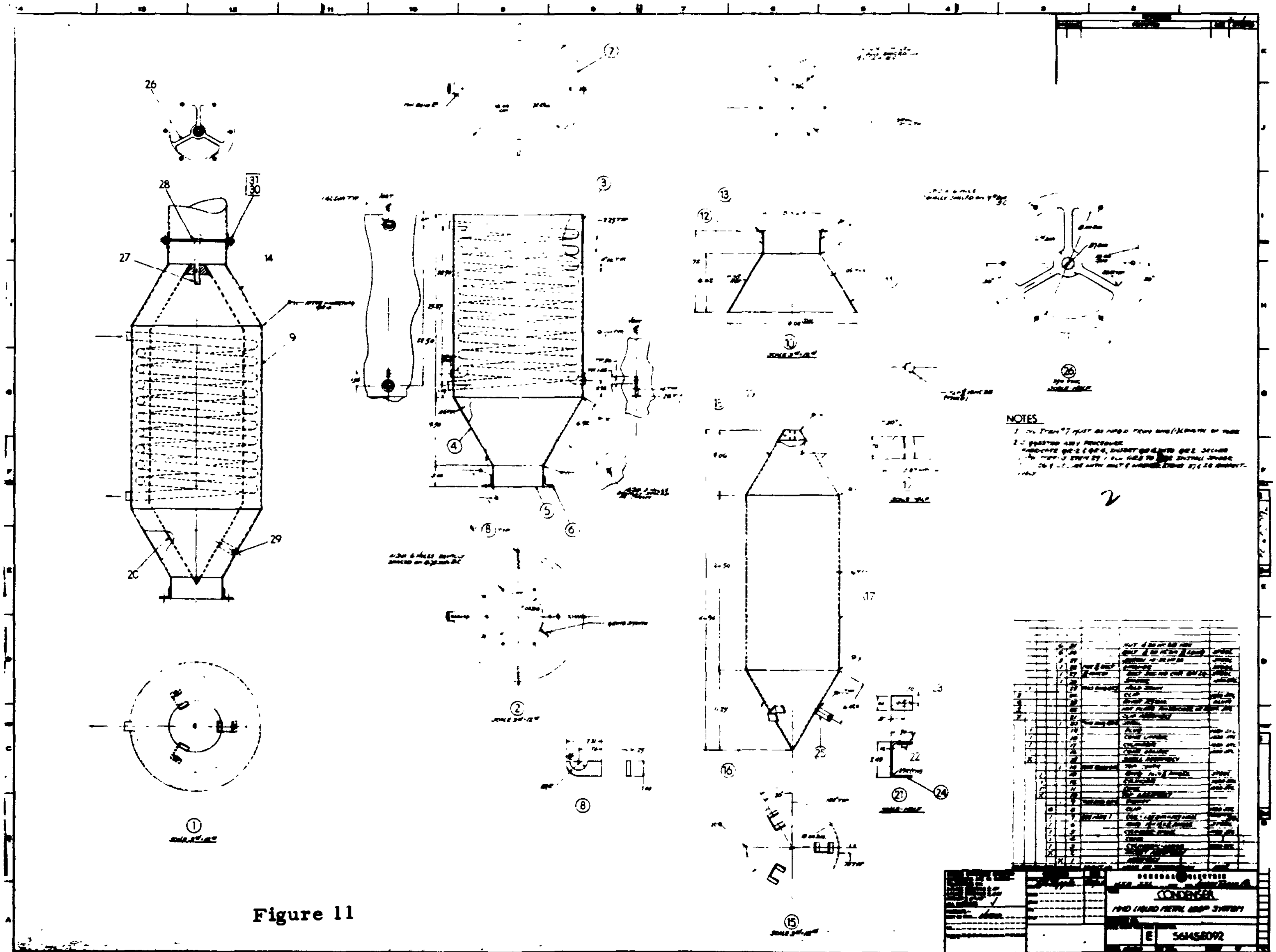


Figure 11

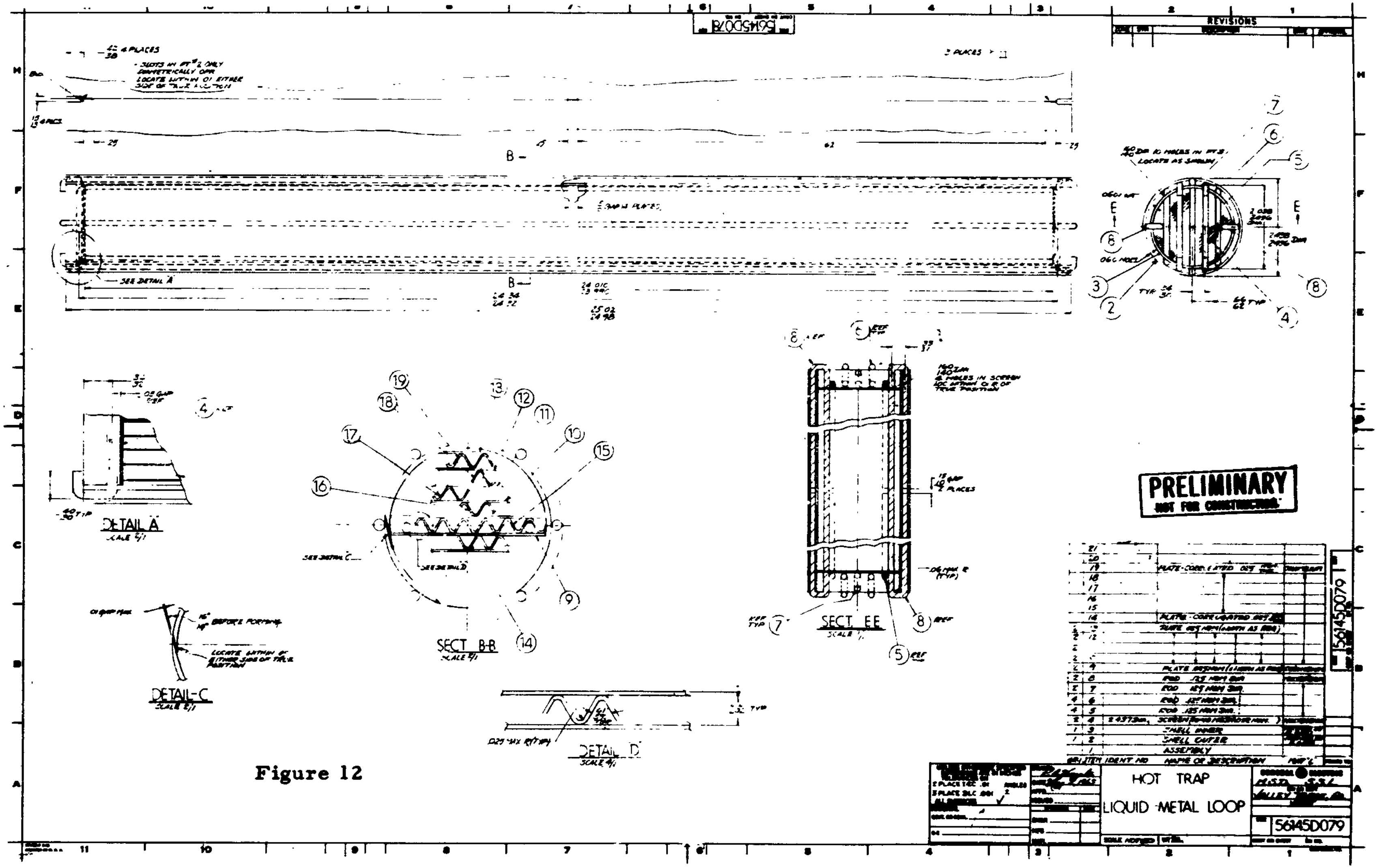

REVISIONS
PRELIMINARY
NOT FOR CONSTRUCTION
DETAIL A
DETAIL-C
SECT B-B
DETAIL D
SECT EE
ASSEMBLY
SHELL OUTER
SHELL INNER
HOT TRAP
LIQUID METAL LOOP
56145D079

Figure 12

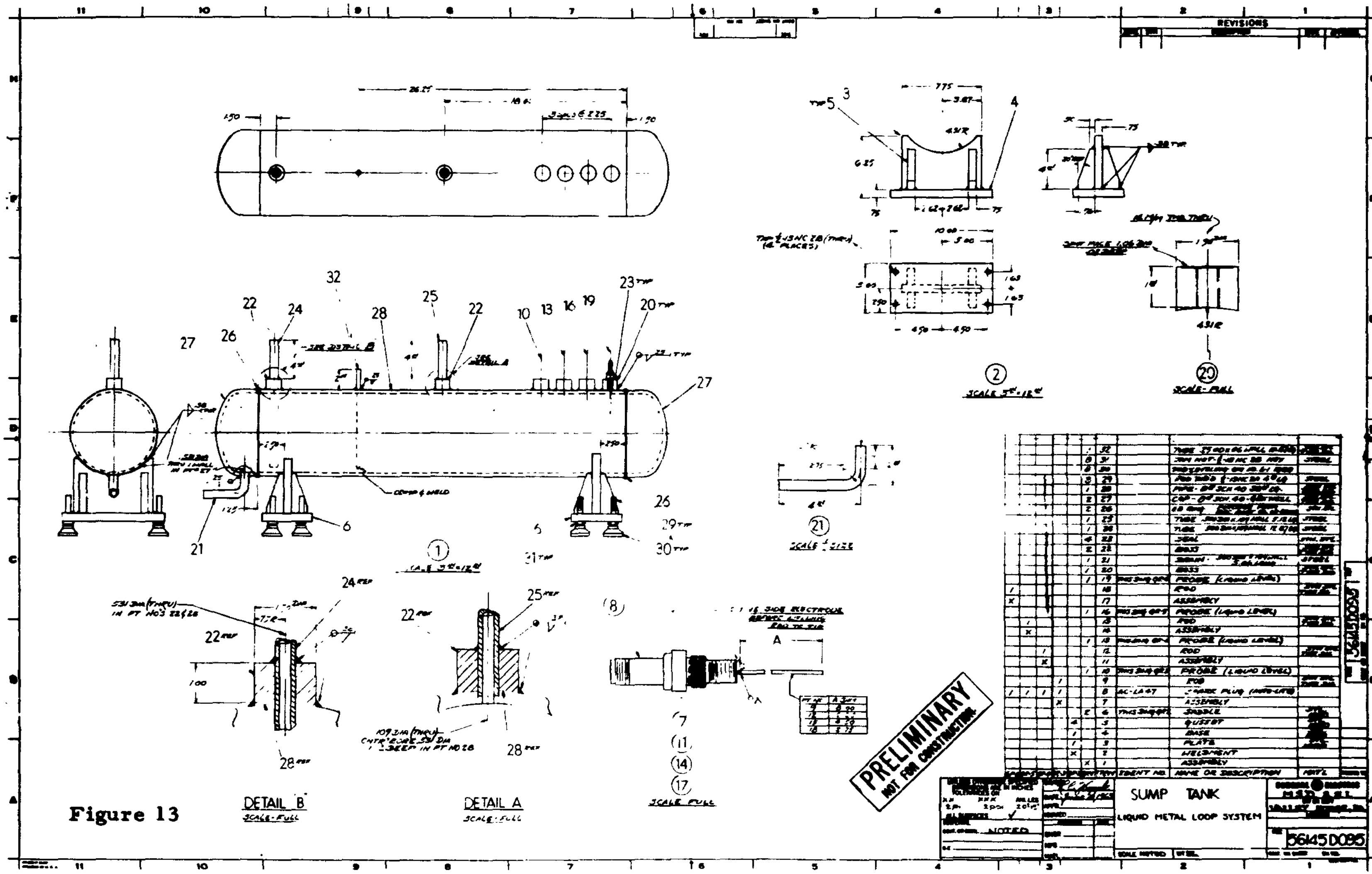
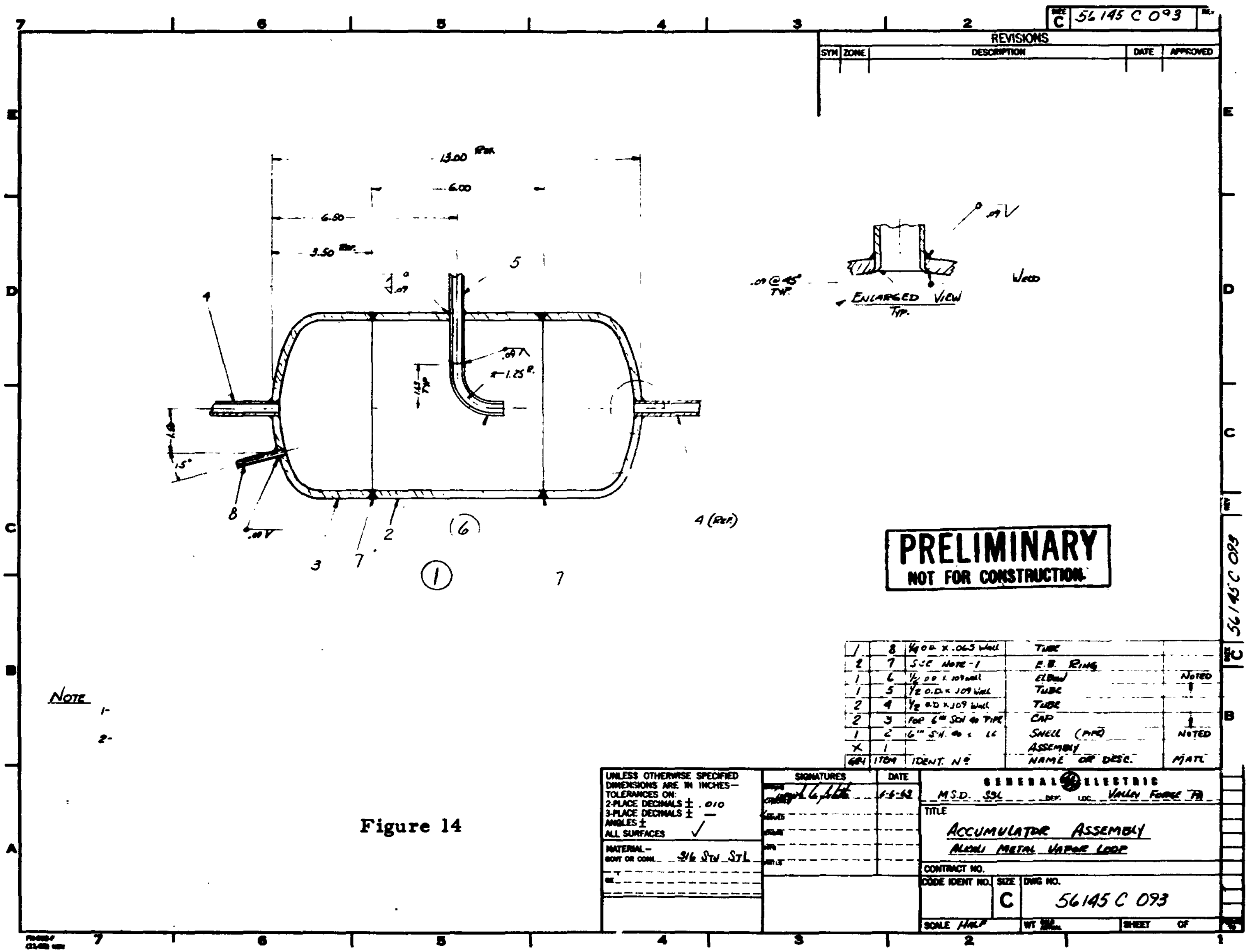

REVISIONS
SUMP TANK
LIQUID METAL LOOP SYSTEM
56145D095
PRELIMINARY
NOT FOR CONSTRUCTION
DETAIL A
SCALE-FULL
DETAIL B
SCALE-FULL
SCALE-FULL
NOTED
NAME OR DESCRIPTION
ASSEMBLY
WELDMENT
PLATE
BASE
GUSSET
SADDLE
PROBE (LIQUID LEVEL)
ROD
BOSS
SEAL

Figure 13



56145 C 093
REVISIONS
SYM ZONE DESCRIPTION DATE APPROVED
13.00
6.00
6.50
3.50
5
4
.09
1.25 R.
15°
8
3
7
2
6
1
4 (REF.)
.09 @ 45° TYP.
ENLARGED VIEW TYP.
WELD
PRELIMINARY
NOT FOR CONSTRUCTION
NOTE 1-
2-
1 | 8 | 1/4 O.D. x .065 Wall | TUBE
2 | 7 | SEE NOTE-1 | E.B. RING
1 | 6 | 1/2 O.D. x .109 Wall | ELBOW | NOTED
1 | 5 | 1/2 O.D. x .109 Wall | TUBE
2 | 4 | 1/2 O.D. x .109 Wall | TUBE
2 | 3 | FOR 6" SCH 40 PIPE | CAP | NOTED
1 | 2 | 6" SCH. 40 x 16 | SHELL (PIPE)
X | 1 | | ASSEMBLY
GR1 | ITEM | IDENT. NO. | NAME OR DESC. | MATL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES—
TOLERANCES ON:
2-PLACE DECIMALS ± .010
3-PLACE DECIMALS ± —
ANGLES ±
ALL SURFACES
MATERIAL— 316 Stn Stl
SIGNATURES
DATE
6-6-62
GENERAL ELECTRIC
M.S.D. SSL DEPT. LOC. Valley Forge PA
TITLE
ACCUMULATOR ASSEMBLY
ALKALI METAL VAPOR LOOP
CONTRACT NO.
CODE IDENT NO. SIZE C DWG NO. 56145 C 093
SCALE HALF
SHEET OF

Figure 14

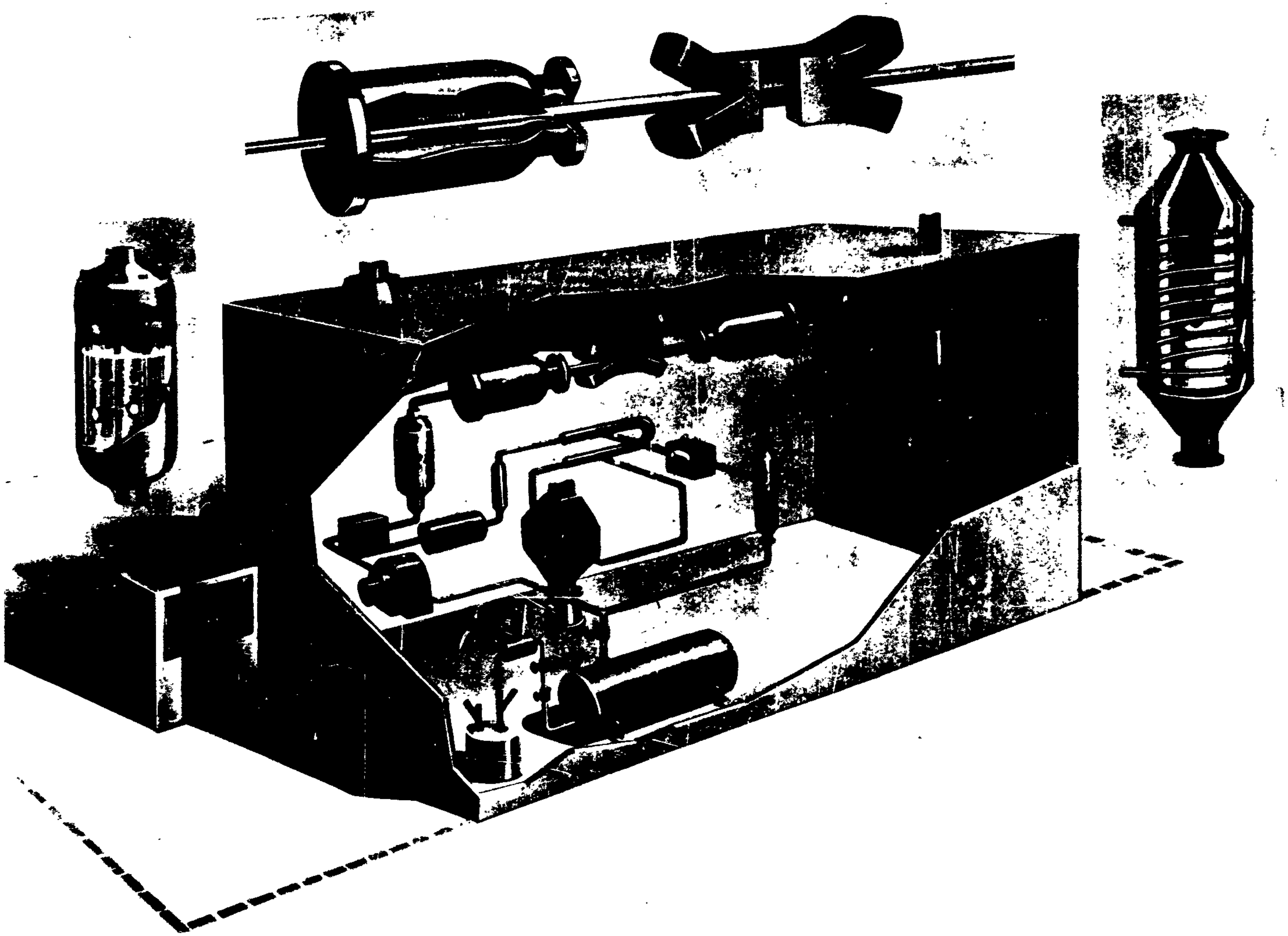
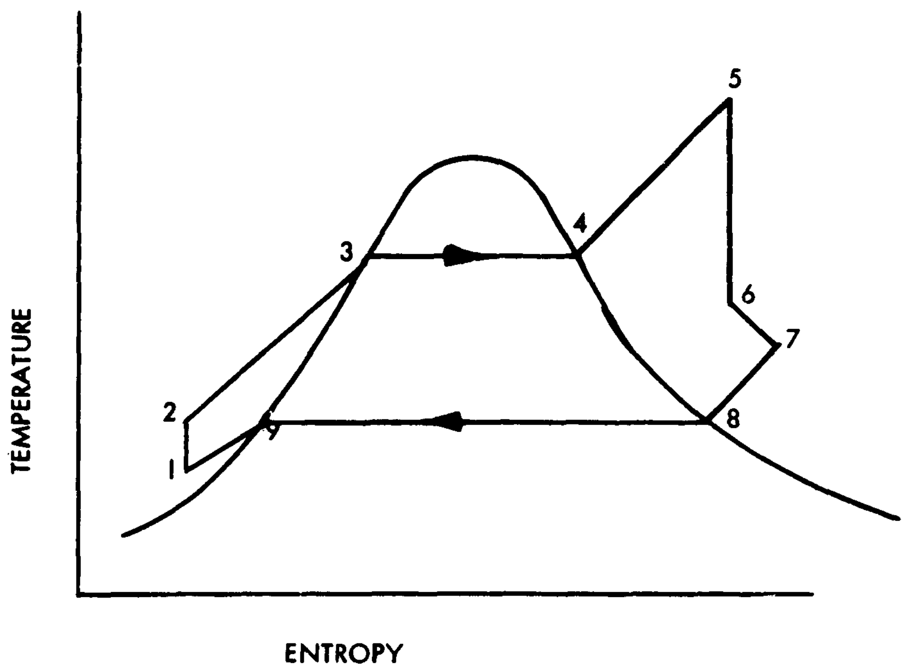


Figure 15



ALKALI METAL VAPOR LOOP - RANKINE CYCLE

1-2 : Pump
2-3 : Heater
3-4 : Boiler
4-5 : Superheater
5-6 : Isentropic Expansion
6-7 : Generator
7-8 : De-superheater
8-9 : Condenser
9-1 : Cooler

Figure 16

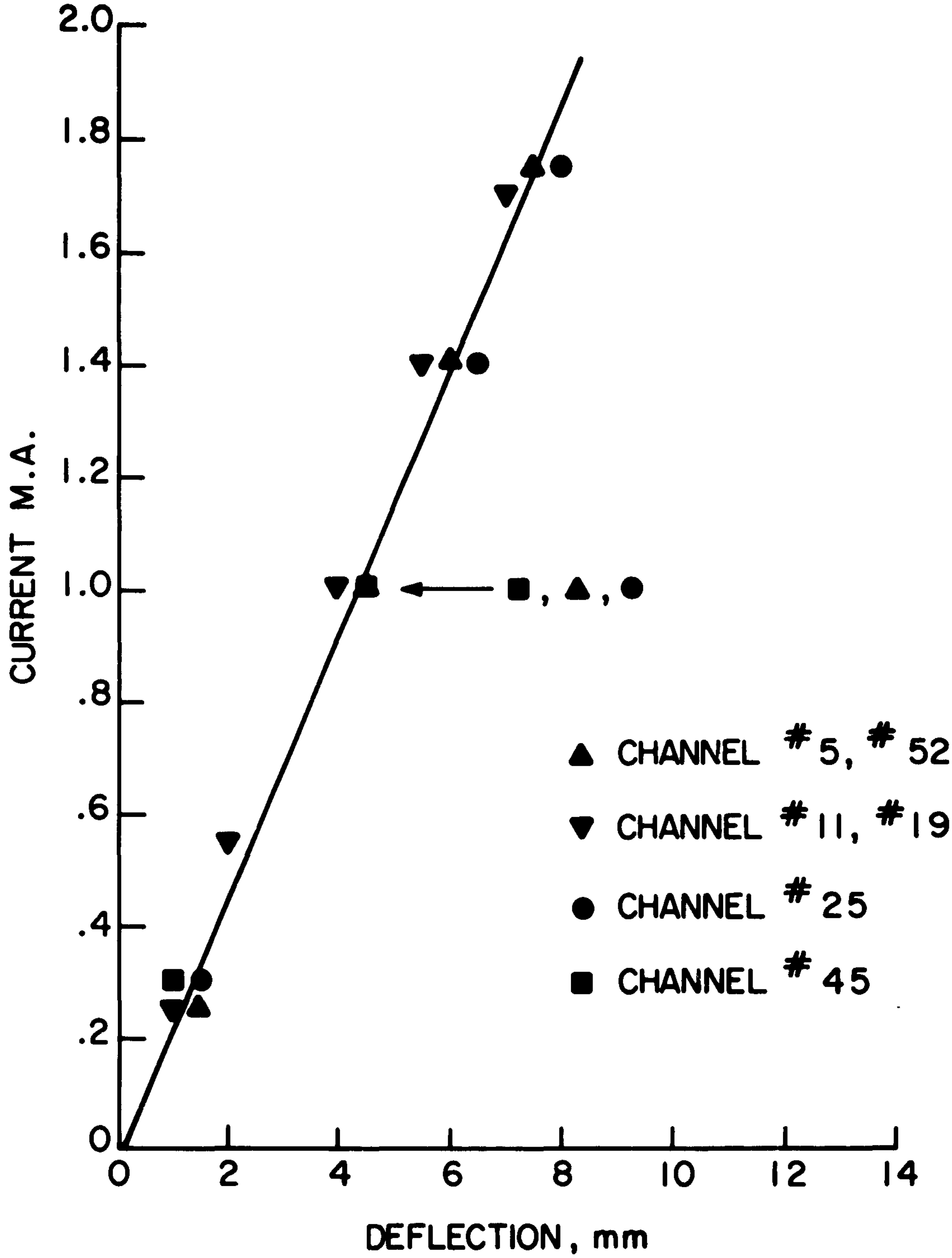


Figure 17. Galvanometer Calibration Curves for PM-22

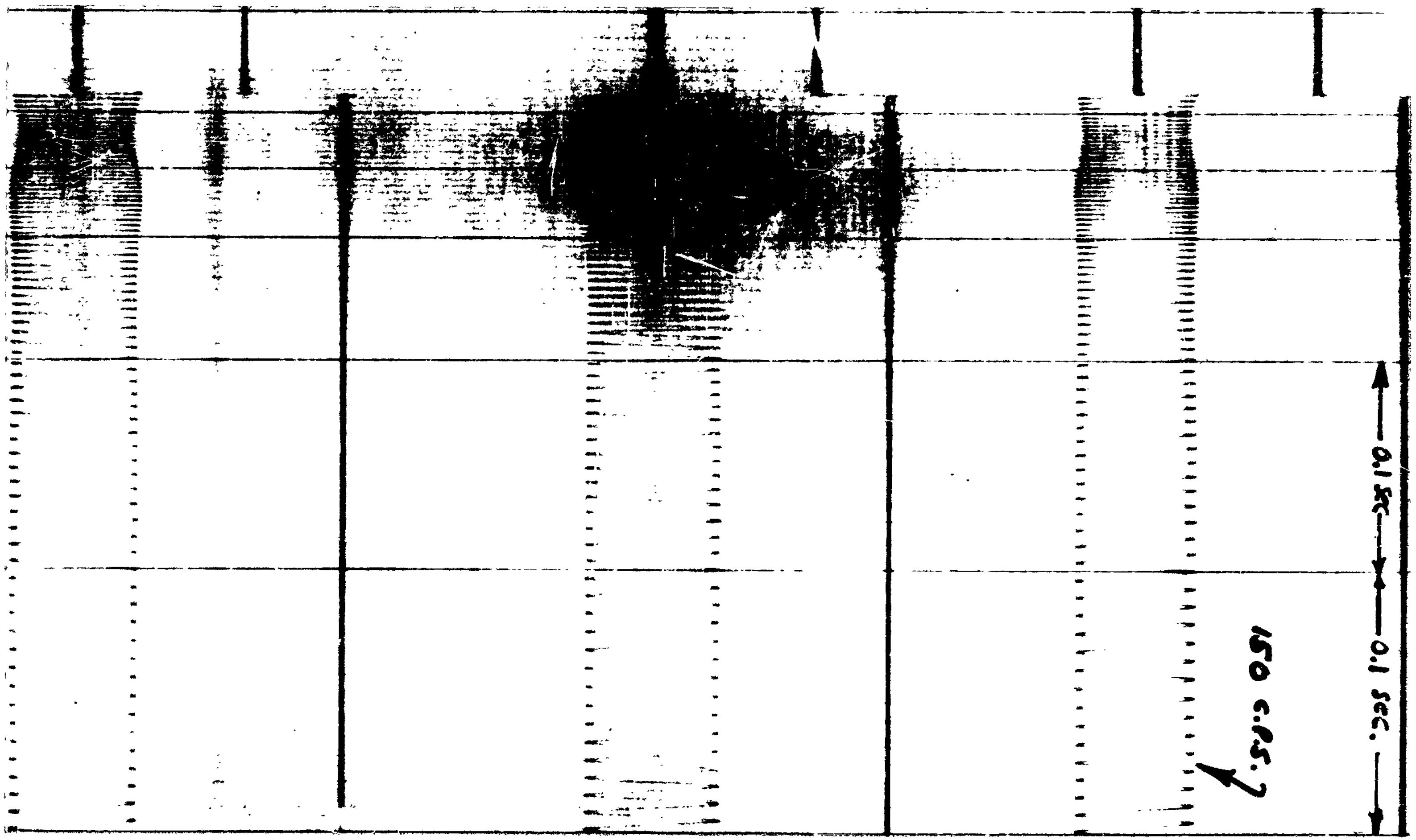


Figure 18. Typical Oscillograms Obtained from the PM-22

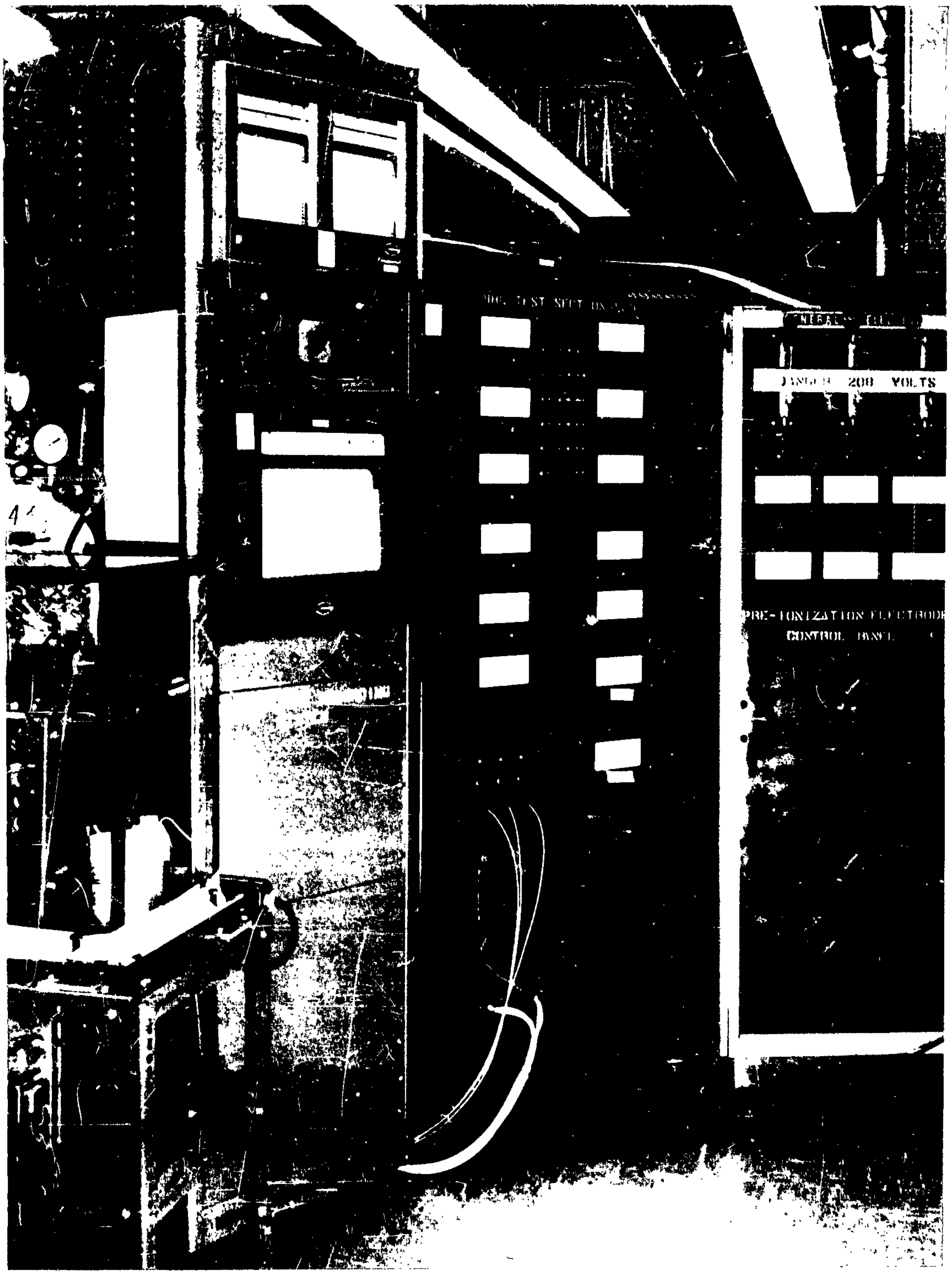


Figure 19

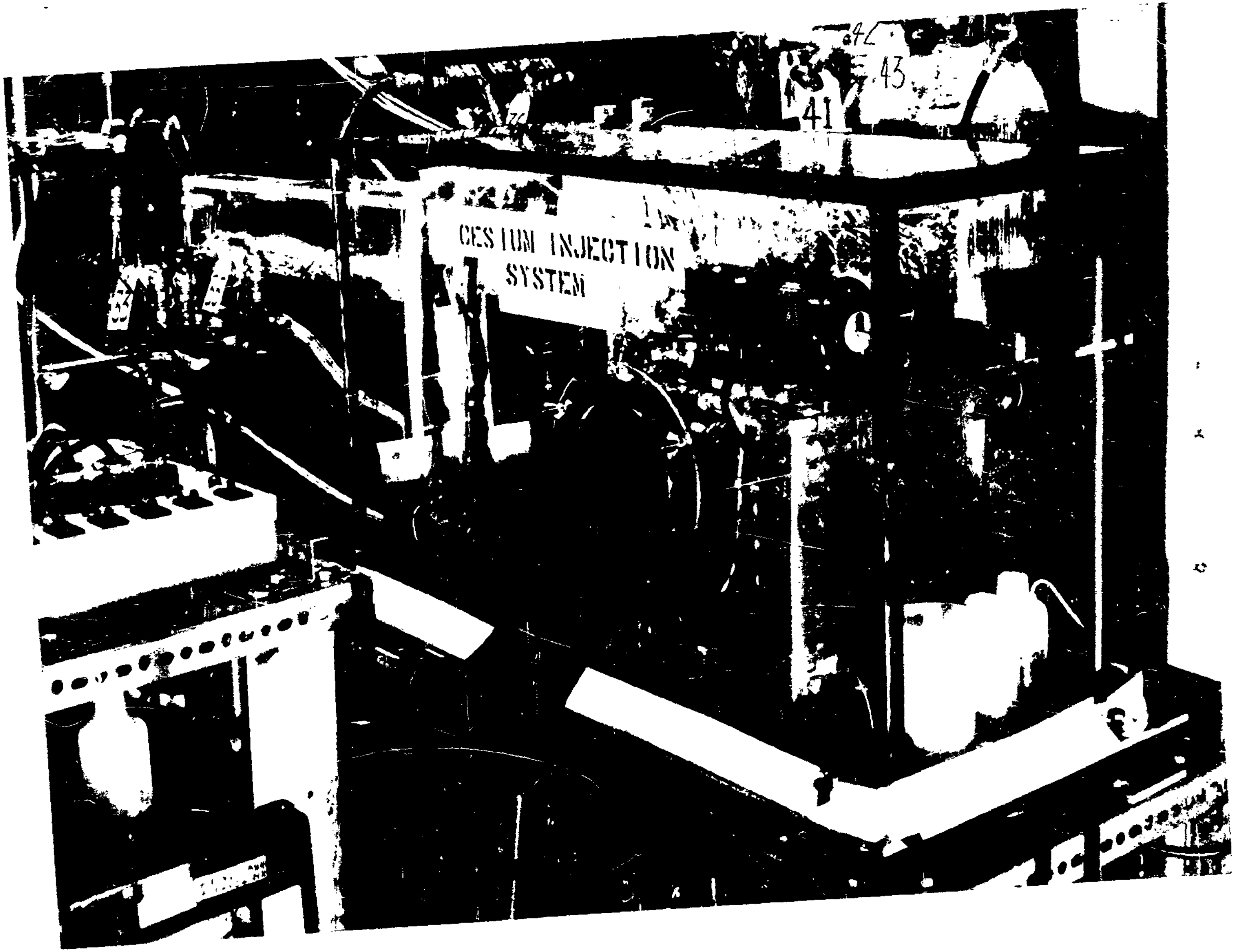


Figure 20

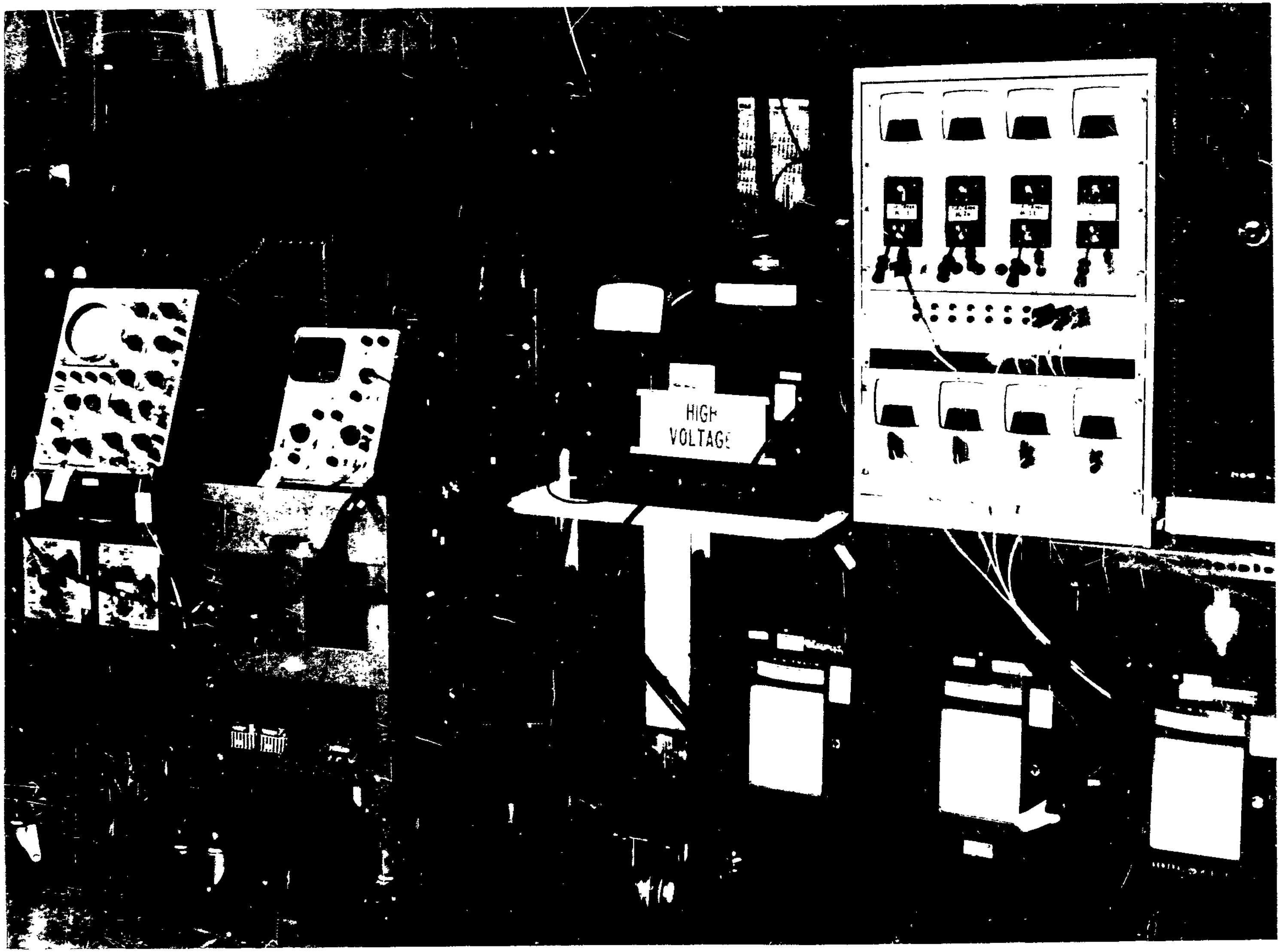


Figure 21

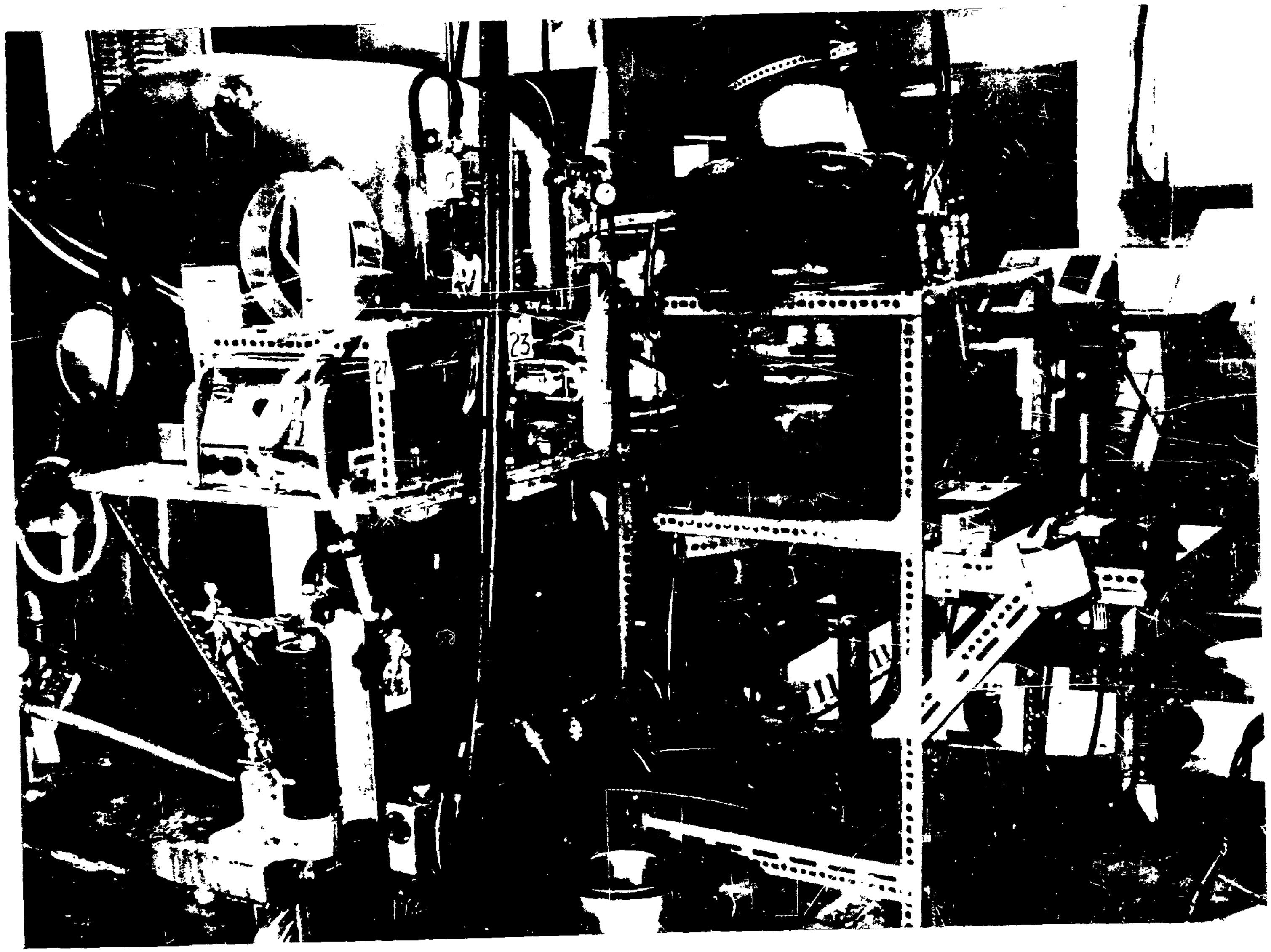


Figure 22

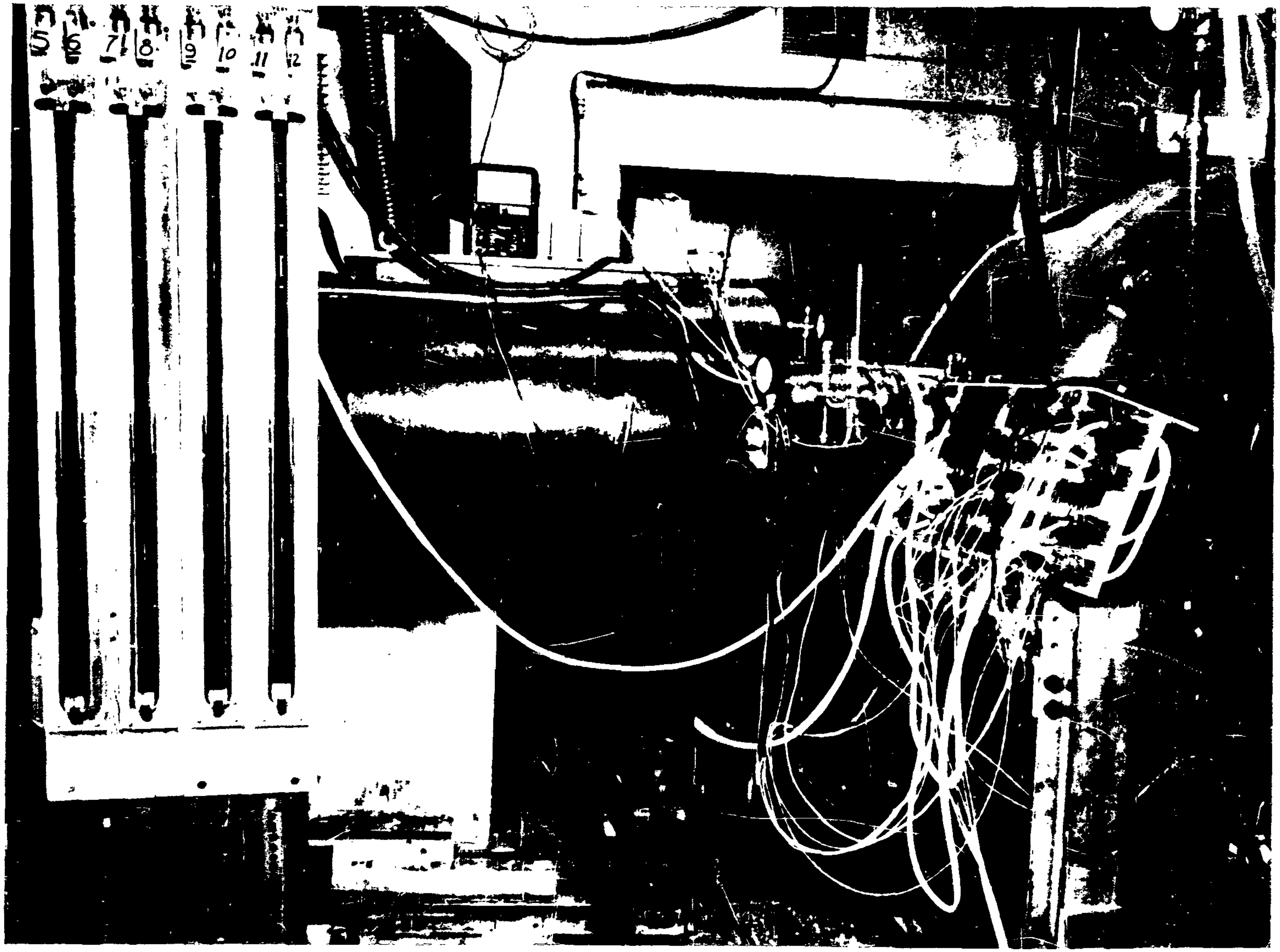


Figure 23

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